N-47
1080-CR

NAS8-3187

Preprints AIAA

P4

NORTHERN VS. SOUTHERN HEMISPHERE ENERGY CONVERSIONS IN JANUARY 1979

James W. Hurrell
Department of Geosciences
Purdue University
West Lafayette, IN 47907

Huo-Jin Huang
Atmospheric Sciences Program
University of North Carolina
Asheville, NC 28804

Dayton G. Vincent
Department of Geosciences
Purdue University
West Lafayette, IN 47907

1. INTRODUCTION

In a recent paper, Huang and Vincent (1985) presented a diagnosis of the zonal and eddy energy conversions in the Southern Hemisphere during the early part of FGGE SOP-1, namely 10-27 January 1979. They found that wave number 4 was tied to the three continents and to the South Pacific Convergence Zone (SPCZ) in the tropics and that the SPCZ region made a significant contribution to the baroclinic conversion, CE, from eddy available potential to eddy kinetic energy. They also found that wave numbers 6-7 dominated each of the energy conversions in middle latitudes. Moreover, transient waves were responsible for nearly all of the total by each conversion term in middle latitudes, whereas the standing eddy contribution accounted for most of the CE-conversion in the tropics. The present study utilizes the same methodology applied by Huang and Vincent in the Southern Hemisphere to diagnose the energetics of the Northern Hemisphere for the same period. Of particular interest is a comparison of the tropical and extratropical energy conversions between the two hemispheres. It should be noted that Price (1975) made a comparison of the energy contents between the two hemispheres for a one-year period. More will be said later regarding his work.

The methodology consists of partitioning the energy contents and conversions into zonal and eddy component equations using three established formats: (1) mixed space-time domain (Oort, 1964) to differentiate between contributions by the mean state and transient and standing eddies; (2) space domain (Brennan and Vincent, 1980) to investigate daily variations; and (3) spectral domain (Saltzman, 1957; 1970) to examine the significance of specific waves to the total energy for wave numbers 1-15.

A detailed description of the data sources and computational procedures used in this paper appears in Vincent (1982) and Huang and Vincent (1985) and is not reiterated here. In summary, the primary data source is a modified set of upper air Level III-b analyses, originally produced by ECMWF. The data consists of grid point values of mean sea level pressure and horizontal wind components, geopotential height, temperature and vertical p-velocity at mandatory pressure levels from 1000-100 mb, all at increments of 5° lat/lon. Two of these variables (T, ω) were initialized in the original ECMWF data set. We recomputed each; the temperature hydrostatically from the height field and the vertical motion kinematically from the wind field making use of an O'Brien (1970) adjustment scheme. Thus, all variables used in this study are based on analyzed variables.

2. RESULTS AND DISCUSSION

In our previous studies we have shown that the SPCZ is a quasi-stationary persistent feature of the Southern Hemisphere circulation during the period 10-24 January 1979. Evidence of this fact is given in Fig. 1 which depicts the time-averaged outgoing longwave radiation (OLR) for that period. Values of OLR were derived from NOAA polar-orbiting satellites and were supplied to us by NESDIS/NOAA. Detailed explanations concerning these radiation measurements can be found in Gruber and Winston (1978) and Winston et al. (1979). In Fig. 1, OLR values $\leq 225\ Wm^{-2}$ at lower latitudes have been shaded since they most likely contain deep convective activity a large percentage of the time (Heddinghaus and Krueger, 1981). It is clear that one of the dominant cloud bands occurs in conjunction with the SPCZ. The other prominent area of convective activity extends from South America to the eastern part of the South Atlantic. The latter phenomenon, which has been referred to as the South Atlantic Convergence Zone (SACZ), is discussed by Huang and Vincent in a paper found elsewhere in this preprint volume. In that paper, the focus is on comparing the energetics between ECMWF and GLA analyses, as well as assessing the role of the SPCZ and SACZ in the general circulation of the Southern Hemisphere. The present paper focuses on an examination of the energetics in specific latitude belts, i.e., the tropics and extratropics of the Northern and Southern Hemispheres.

Figure 2 shows the time-averaged mixed space-time domain results for the energy contents and conversions for the Northern Hemisphere (60°N-0°), Southern Hemisphere (0°-60°S), and the tropical (30°-0°) and mid-latitude (60°-30°) sectors of each hemisphere. Several points are worth noting. All of the contents and the CA and CE conversions are greater in the Northern Hemisphere than in the Southern Hemisphere. This is not too surprising since the time period occurs in the middle of northern winter. The eddy portion of the energy cycle is the same in both hemispheres with a conversion

(NASA-CR-180044) NORTHERN VERSUS SOUTHERN HEMISPHERE ENERGY CONVERSIONS IN JANUARY 1979 (Purdue Univ.) 4 p

N87-70253
49080

Unclas
00/47 43851

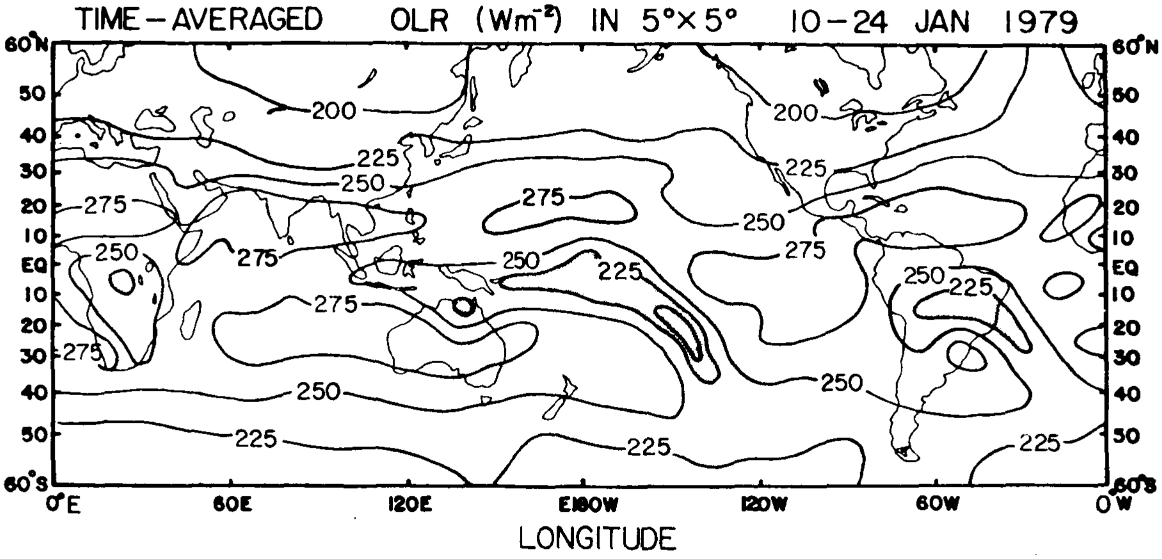

Fig. 1. Time-averaged outgoing longwave radiation for 10-24 January 1979. Areas with OLR $\leq$ 225 Wm^{-2} in tropics are shaded to represent regions which most likely contain deep convective systems.

of AZ→AE→KE→KZ. In general the transient eddy contributions to contents and conversions are greater than the standing eddy contributions, but not significantly greater. Within the subregions it is seen that the tropical sector of each hemisphere is considerably less active (energetically) than the middle latitude sectors. Again, this is not too surprising. However, one significant feature of the energy cycle is the importance of the standing eddy component of CE in the Southern Hemisphere tropics. This feature was eluded to in the Introduction and is one of the main topics of discussion by Huang and Vincent (1985). They found that when the SPCZ (which was a quasi-stationary feature of the circulation) was convectively active during the 10-24 January period, the conversion of AE to KE was very strong. After 24 January, when the SPCZ weakened and decayed, the CE conversion, both in the SPCZ area and in the total 0-30°S belt, decreased substantially. Furthermore, wave number 4 was dominant in the tropical belt when the SPCZ was active. Our analysis shows no counterpart of this wave activity in the Northern Hemisphere tropics during the period. It is interesting to note that Price (1975) found wave number 4 made an important contribution to the eddy kinetic and potential energy contents of the Southern Hemisphere for a one-year period beginning May 1972.

It is obvious in Fig. 2 that the most energetically active regions are in middle latitudes, particularly in the Northern Hemisphere. The energy cycle in northern winter is dominated by a conversion of AZ to AE and AE to KE. In these conversions, both transient and standing eddies are important. One of the more surprising aspects of the cycle is the small value of CK, which shows a weak transport of momentum down the wind gradient. The normal situation in northern winter is for a much stronger conversion of KZ to KE in mid-latitudes. In the Southern Hemisphere mid-latitudes, none of the energy conversions are negligible and the transient wave effects dominate the eddy conversions. A more detailed discussion of this region's energetics is found in Huang and Vincent (1985).

Since CA and CE in the extratropical regions are the most significant energy conversions, the remainder of the paper focuses on these two quantities. Figure 3 shows a time series of CA and CE, derived from space domain equations, for 60°-30°N and 30°-60°S. In general, the trend of CA is the same as that of CE in both hemispheres. In addition, the magnitudes are comparable. This implies that the two conversions are taking place nearly simultaneously, that is, sensible heat is being transported horizontally from warm regions to cold regions and, on the same time scale, the warmer air is rising while the colder air is sinking. As noted earlier, the intensity of this circulation is greater in the Northern Hemisphere.

The spectral energy diagnosis performed by Huang and Vincent (1985) for the Southern Hemisphere mid-latitudes showed that all of the eddy energy conversion terms had a peak in wave numbers 6 and 7. Their graphs of CA and CE are reproduced in Fig. 4, together with similar graphs for the Northern Hemisphere. It is seen that, as for the day-to-day changes, plots of the two conversions in wave number domain are similar. In the Northern Hemisphere, the maximum value of CA and CE occurs at n=2. There also is an important contribution to the energy spectrum at intermediate wavelengths, with a peak at n=7. Thus, in both hemispheres the larger synoptic-scale (Rossby) waves are in important in the AZ→AE→KE conversion. However, in the Northern Hemisphere the long waves make the most significant contribution to this conversion cycle, whereas in the Southern Hemisphere the intermediate waves dominate.

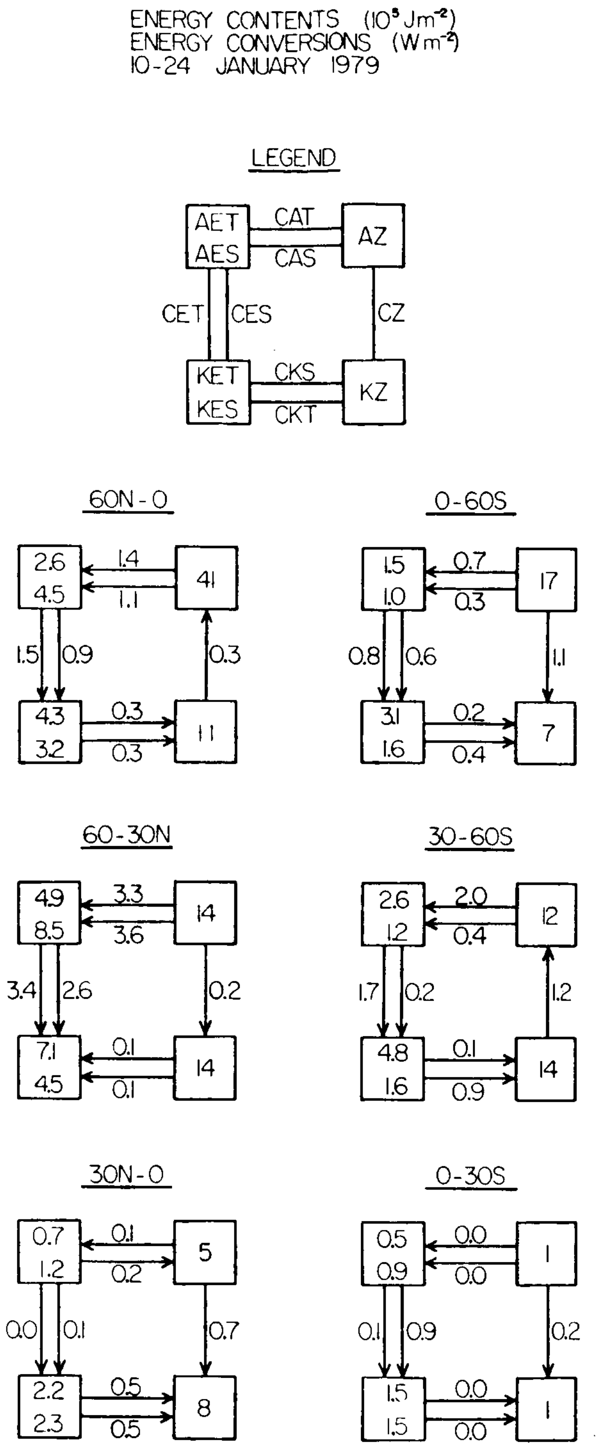

Fig. 2. Time-averaged energy contents and conversions from space-time domain equations for 10-24 January 1979. Transient and standing eddy contributions are indicated by T and S.

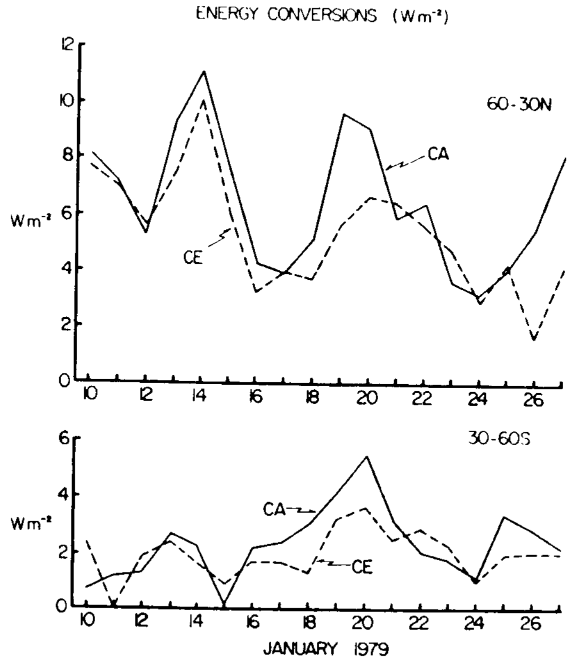

Fig. 3. Time series of energy conversion, CA and CE in middle latitudes of each hemisphere.

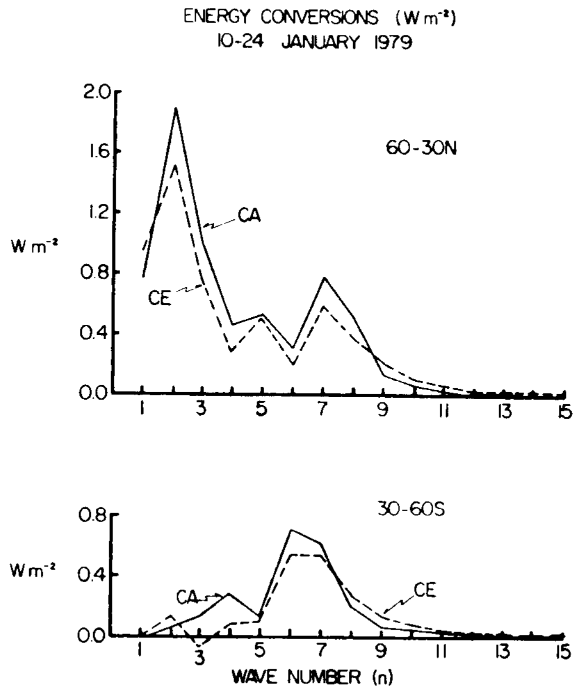

Fig. 4. Time-averaged energy conversions, CA and CE, as a function of zonal wave number for middle latitudes of each hemisphere for 10-24 January 1979.

ACKNOWLEDGEMENTS

The authors thank Drs. Julia Paegle and John Ward for their assistance in supplying them with the ECMWF data. Also, they appreciate the help provided by Mr. Douglas Miller who drafted the figures and Ms. Helen Henry who typed the manuscript. The research was sponsored by the Global Atmospheric Research Program, Division of Atmospheric Science, National Science Foundation and the National Oceanic and Atmospheric Administration under Grant Number ATM 8405748 and by the National Aeronautics and Space Administration under Contract Number NAS8-35187.

REFERENCES

Brennan, F.E., and D.G. Vincent, 1980: Zonal and eddy components of the synoptic-scale budget during intensification of Hurricane Carmen (1974). Mon. Wea. Rev., 108, 954-965.

Gruber, A., and Winston, J.A., 1978: Earth-Atmosphere radiative heating based on NOAA scanning radiometer measurements. Bull. Amer. Meteor. Soc., 59, 1570-1578.

Heddinghaus, T.R., and A.F. Krueger, 1981: Annual and interannual variations in outgoing longwave radiation over the tropics. Mon. Wea. Rev., 109, 1208-1218.

Huang, H.-J., and D.G. Vincent, 1985: Significance of the SPCZ in energy conversions of the Southern Hemisphere during FGGE, 10-27 January 1979. Mon. Wea. Rev., 113, 1359-1371.

O'Brien, J.J., 1970: Alternative solutions to the classical vertical velocity problem. J. Appl. Meteor., 9, 197-203.

Oort, A.H., 1964: On the energetics of the atmospheric energy cycle. Mon. Wea. Rev., 92, 483-493.

Price, P.G., 1975: A comparison between available potential and kinetic energy estimates for the Southern and Northern Hemispheres. Tellus, 27, 443-452.

Saltzman, B., 1957: Equations governing the energetics of the larger scales of atmospheric turbulence in the domain of wave number. J. Meteor., 14, 513-523.

Saltzman, B., 1970: Large-scale atmospheric energetics of the wave number domain. Rev. Geophys. Space Phys., 8, 289-302.

Vincent, D.G., 1982: Circulation features over the South Pacific during 10-18 January 1979. Mon. Wea. Rev., 110, 981-993.

Winston, J.A., A. Gruber, T.I. Gray, Jr., M.S. Varnadore, C.L. Earnest and L.P. Mannello, 1979: Earth-Atmosphere Radiation Budget Analyses Derived from NOAA Satellite Data June 1974-February 1978. Vol. 1, NOAA, Washington, D.C., 373 pp.